RESIDUAL EFFECTS OF FORESTRY HERBICIDES ON FLORISTIC DIVERSITY, STAND STRUCTURE AND COMPOSITION ELEVEN YEARS AFTER SITE PREPARATION TREATMENTS

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Introduction

The global conservation of biodiversity will require efforts at multiple levels to be successful. Because herbicides are applied annually to 100,000's of hectares of forest lands in the Southeastern Region, U.S.A., it is crucial we know their short-term and long-term impacts on forest biodiversity, structure, and composition. It is recognized that effective applications of forestry herbicides initially decrease floristic diversity (Blake *et al.* 1987, Wilkins *et al.* 1993, Zutter and Zedaker 1988). Composition is altered because species are differentially controlled. But for how long? Structural changes are initiated because crop tree growth is usually increased. But how do alterations in structural dynamics influence diversity and composition of mid-story and understory species? Only the companion study to the current study, which examined pine release treatments (Boyd *et al.* 1995), has examined longer term changes in plant diversity related to earlier applications of forestry herbicides. In this current research, we tested for residual effects of site preparation applications made 11 years earlier on plant species richness, diversity, and stand structure and composition.

Materials and Methods

Four study sites in three physiographic provinces in Central Georgia, U.S.A., were established in 1984 on areas that were biomass harvested and allowed to regrow. More complete site and study details, as well as, pine growth response up to Year 6 have been presented in Miller and Edwards (1995). Herbicide plots on each site included glyphosate (4.5 kg ai ha^{-1}), triclopyr (4.4 kg ae ha^{-1}), a mixture of dicamba and 2,4-D (4.5 kg ae + 4.5 kg ae ha^{-1}, later referred to as just dicamba), picloram pellets (3.4 kg ae ha^{-1}), liquid and pelleted hexazinone (2.8 to 3.9 kg ai ha^{-1}), plus an untreated check. Hexazinone was prescribed according to soil texture and soil organic matter per label recommendations. Plot sizes averaged 0.4 ha and plots were generally contiguous per site. Applications were by a sprayer or a spreader mounted on crawler tractors that had onboard micro-processor systems linked to speed sensors to maintain rate with varying ground speed. Sites were prescribed burned in the Fall and planted to loblolly pine (*Pinus taeda* L.) at a 1.8 m x 2.7 m spacing.

At the start of the eleventh growing season post-treatment (1995), 20 nested quadrats were established within each treatment plot (within a 0.13-ha interior net plot) by a stratified random procedure (560 nested plots). The understory layer (<1.5 m tall) was surveyed using 2 m x 2 m quadrats. Species were listed in June-July and their percent canopy cover visually estimated. Other visits in April and September allowed identification and cover estimates for species active at other times of the year. Overstory species (>1.5 m tall) were measured in September using circular 0.005-

ha plots. Stem and rootstock numbers were recorded for arborescent and nonarborescent woody species. In addition, dbh of arborescent stems and height of nonarborescent stems were measured. A randomized complete block model ANOVA was used, with sites considered as blocks. Species diversity was examined for each canopy layer separately using the Shannon-Wiener diversity index. Diversity calculations for the overstory used density data for woody species averaged by plot, and understory diversity calculations used averaged cover by species. Species present on all Checks were further examined by Importance Values (IVs), which combined measures of relative abundance and relative frequency. Variables that represent percentages (e..g., IVs) were arc-sine square-root transformed and variables representing counts were square-root transformed prior to analysis. Tukey's Compromise Test was used for post-hoc mean separation.

Results and Discussion

Tree canopies were just closing in these 10-year-old tree plantations. A total of 177 plant species were identified, indicating a considerably richer flora than often assumed for pine plantations. Species richness did not significantly differ by treatment (α=0.05), averaging 50 to 61 species per plot (Table 1). Over half the species were arborescents (16-19 species per plot) and forbs (11 to 19 species per plot). As indicated by the Shannon-Wiener Index, treatments also had no detectable residual effect on diversity for either the overstory or understory layers. The close proximity of plots at each site would result in common seed rain and probably similar soil seed banks, which should minimize differences in composition, especially in the herbaceous component.

Overstory structure, as determined by total basal area (BA), was similar for all treatments (ANOVA P=0.16), but there were significant differences in the hardwood and pine components. Pine BA was a significant two-fold greater on the hexazinone and glyphosate treatments compared to the Check (per Tukey's Test). Conversely, hardwood BA was a significant two- to three-fold greater on the Check compared to the hexazinone treatments. Not only was overstory structure significantly influenced by treatment, but also species composition was significantly different. Nine arborescent taxa were present in all Check plots (presence in all Check plots was the criterion for further analysis). Of these, IVs were significantly different for *Pinus taeda*, *Prunus serotina* Ehrh., *Quercus stellata* Wangengh., and *Diospyros virginiana* L. These are important species for the eventual production of hard and soft mast for wildlife food.

In the stands' mid-story, shrub abundance also differed significantly by treatment. The four-fold greater number of nonarborescent woody stems on picloram treatments was significantly greater than that found on plots treated with hexazinone pellets. Only two nonarborescent taxa, *Vaccinium* spp. and *Rhus copallinum* L., were present on all Checks, but neither differed significantly by treatment. Understories of these plantations were dominated by woody plants. Arborescent, woody vine, and nonarborescent growth forms were predominant, with mean IVs for each growth form ranging from 19% to 77%. Forbs, grass/grasslike species, and semiwoody species were secondary dominants, with mean IVs ranging from 15% to 37%. Ferns had a very minor presence, with a maximum mean IV of 2.3% (hexazinone liquid). Three understory species also recognized for their wildlife food values appeared to have been significantly affected by treatment. *Vaccinium stamineum* L. had highest IV values on dicamba plots and significantly lower values on glyphosate treatments. *Vitis rotundifolia* Michx. had its peak IV on Check plots and a significantly lower IV on dicamba

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treatments. The exotic invasive species, *Lespedeza bicolor* Turcz., was absent on hexazinone-liquid plots and had a significantly higher IV on triclopyr treatments.

Table 1. Herbicide Site Preparation Effects 11 Years After Treatment on Species Richness and Overstory and Understory Diversity, Structure and Composition.*

Variable	Check	Glyphosate	Triclopyr	Dicamba	Picloram	Hex. liquid	Hex. pellet	ANOVA (p-value)
Total species (number plot^{-1})	55	59	61	53	53	58	50	0.2681
Overstory								
Shannon-Wiener Index	2.3	2.2	2.1	2.0	2.1	2.1	2.0	0.6707
Pine BA (m^2 ha^{-1})	9.7 a	17.9 b	16.1 ab	17.1 ab	16.2 ab	20.3 b	19.7 b	0.0131
Hardwood BA (m^2 ha^{-1})	9.8 a	5.9 ab	5.9 ab	5.7 ab	7.0 ab	3.3 b	4.6 b	0.0119
Pinus taeda IV	26.0 b	40.0 ab	42.0 ab	36.0 ab	36.0 ab	50.0 ab	55.0 a	0.0444
Prunus serotina IV	15.0 ab	14.0 ab	19.0 a	11.0 ab	12.0 ab	9.2 a	9.3 b	0.0345
Quercus stellata IV	6.9 a	4.1 ab	4.1 ab	3.2 ab	7.2 a	3.2 ab	2.5 b	0.0125
Diospyros virginiana IV	3.3 bc	5.1 abc	5.0 abc	2.0 c	4.8 abc	11.0 a	9.2 ab	0.0072
Nonarborescent woody stems (no. ha^{-1} X 1,000)	2.0 a	1.0 ab	0.9 ab	1.0 ab	0.7 a	2.3 ab	3.1 b	0.0236
Understory								
Shannon-Wiener Index	2.8	2.8	2.8	2.6	2.6	2.7	2.6	0.4431
Vaccinium stamineum IV	6.5 ab	2.4 b	5.5 ab	13.0 a	7.1 ab	7.0 ab	8.0 ab	0.0104
Vitis rotundifolia IV	11.0 a	6.2 ab	2.7 ab	1.8 b	2.7 ab	2.4 ab	5.7 ab	0.0473
Lespedeza bicolor IV	1.4 a	0.7 ab	2.5 a	1.3 ab	1.7 a	2.1 a	0.0 b	0.0083

* Values in a row followed by the same letter are not significantly different at α=0.05 as determined by Tukey's test.

Herbicide treatments did not significantly alter species richness, diversity, or total overstory and understory abundance 11 years post-treatment, compared to burned-only check stands. Structural differences in the proportion of overstory pines to hardwoods had been significantly altered, as well as shrub abundance. Examination of individual species found treatments significantly affected the abundance of hard and soft mass producing species that will influence wildlife habitat values.

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